dRICH prototype and tests

The dRICH prototype and related tests are required to end-up with a Conceptual Design Report (CDR), where should be reported:

1. baseline detector components that are proposed (possibly with options) and must be justified;
2. detailed performances of the detector baseline, based on simulation and prototype for critical aspects;
3. costs estimates

At the end of this fiscal year a detailed simulation (based on GEMC) and related characterization of the dRICH performances will be available.
These performances are strongly affected by the optical (and physics) properties of the radiators and the specs of the photon detector.
The main inputs of the simulation concerning the aerogel have been inferred from similar devices built in the past (HERMES and LHCb RICHes) and from the undergoing activity of the CLAS12 RICH collaboration.
For the gas radiator, C_2F_6 is the current baseline and its main parameters have been either derived or extrapolated from the literature and, for the number of expected Cherenkov photons, from the more established knowledge of the properties of CF_4 gas.

The choice of the photo-detector, is probably largely driven by the capability of working in magnetic field and costs; however compactness should be considered as an important requirements in order to adapt the photon detector surface to the peculiar focal surface of the RICH optics.

The fundamental aspects that need further investigations for the CDR are:

a) **The aerogel:** essential parameters for the simulation (and therefore the performances of the detector) are: transmittance, dispersive relation, Rayleigh scattering (dominant for photon's wavelength below 300 nm), number of Cherenkov photons; additional parameters are the uniformity of the refractive index on the tile, planarity of the tiles ...
According to the current analysis the optimal aerogel refractive index is 1.02. Aerogel with such a refractive index has been recently tested/characterized (see https://arxiv.org/abs/1607.05264) where the aerogel tiles come from the BLAST experiment and have been manufactured by Matsushita Electric Works, Ltd. This characterization can be used in the simulation together with the scaled data from CLAS12 RICH which uses n=1.05 aerogel from Novosibirsk; as far a we know, Novosibirsk is nowadays the unique producer of good optical quality aerogel, since Matsushita do not sell aerogel anymore.
Therefore, assuming the EIC aerogel will be produced from Novosibirsk, no direct data are available for this aerogel.
In fact, the optical quality of the Novosibirsk's aerogel should be better, but on the other hand the Matsushita's aerogel proved to be aging resistant (also HERMES RICH used n=1.03 Matsushita's aerogel). Indeed LHCb RICH used aerogel by Novosibirsk, which did not perform as expected, according to the recent publications, especially in high occupancy regime. The Russian aerogel is not hydrophobic (so non trivial handling care may be required).

CLAS12 is and will continue to be an important source of information about the Novosibirsk aerogel; however CLAS12 uses aerogel with refractive index of 1.05 (as well as the space station experiment AMS-2), while
n=1.02 is expected to be more fragile and somehow more difficult to handle and its optical characteristics maybe different (possibly better) than n=1.05. Moreover aging need to be verified.
Therefore aerogel for dRICH need to be optically characterized (the current source of information are extrapolated as mentioned) at least in terms of: transmittance, dispersion relation, and number of directive Cherenkov photons (without/with different potential filters). Moreover its aging shall be investigated,with or without contact to the gas radiator (possibly when irradiated by ionizing particles).

b) **The gas :** essential parameters are the number of Cherenkov photons and chemical properties. Available information on the “golden” C_2F_6 gas are relatively poor; realistic number of photons is important to consolidate the momentum range and PID power of the dRICH. As mentioned its interplay with the aerogel (chemical interaction aging etc …) is fundamental (especially considering the LHCb results). Also important is the measurement of its scintillation level.

c) The photo-detector : to really express a consolidated baseline tests of the existing options and their comparisons are mandatory.
Magnetic field tolerance, radiation tolerance, and costs will be probably the key parameters. In a short time scale the synergy with CLAS12 and mRICH will represent the best way to proceed.
If one go toward the SiPM option, probably some sort of cooling need to be provided (also for radiation-hardness improvement) and this may results problematic (though solvable) with the optimized “adaptive” photon detector surface of the dRICH.

Some aspects of a), b), c) can be tested in laboratory; but there are fundamental properties (e.g. number of “directive” photons) to be tested in a real prototype even if the dual-radiator RICH solution is somehow “standard”. The negative experience of LHCb is an important warning in this sense. It is worth to point out that only two big dual-radiator (aerogel and gas) RICH detectors operated in the past; and, for the aerogel side, while the HERMES RICH operated well, the LHCb RICH did not. So “standard” is not a synonymous of well established technology: an aerogel based dual-radiator RICH is a challenging detector even in a “standard” configuration.

At the moment, aerogel seems to be essential to cover the important momentum region of 4 to 12 GeV; no other radiator seems to be able to do than (except pressurized gases). In fact LHCb, due to the malfunctioning of the aerogel, were not able to distinguish kaons from protons in such a momentum region, see Figure 6 in arXiv:1703.08152 and continues to be unable to do than without aerogel, in RUN II as well.

Prototype design studies

A minimal “small scale” prototype for a beam test shall include:

- 2 or 3 tiles of aerogel (around 2 cm thick)

- 4 identical photon detectors (to contain the whole gas ring, at least); main eligible photon detectors are PMTs, SiPMs and MCPs.
- a light tight box able to contain the gas, a gas tank (a sort of cylindrical gas tank could be a cheap solution), approx. 1 m long (to get a reasonable number of photons from the gas)
- 1 or 2 cylinders of gas
- a small mirror (30x30 cm^2 or so, optically characterized, approx. 2 m radius of curvature, to get the focal surface near the entrance of the RICH box)
- additional material: mechanical design, mechanical supports etc …

Part of this material can be shared in synergy with the mRICH or the DIRC activity; CLAS12 RICH prototype parts may also be used (Evaristo Cisbani, Marco Contalbrigo and Marco Mirazita suggestions very valuable) .
In the following images a simple (but realistic) prototype configuration has been simulated in GEMC, assuming:

1. the photon detectors shall cover the whole gas ring
2. the same photon detectors will be used, in different runs, for the aerogel photons, either reflected or direct
3. minimal size of the container

Figs. 1, 2 and 3 show the minimal setup simulated in GEMC, assuming the beam traveling along the axis of the cylindrical box (probably not the optimal solution to cover the aerogel ring). The gas ring parameters (radius and center) can be reconstructed event by event by event by fitting the hits (Figs. 4 and 5) without the MC reconstruction algorithm; this should be rather unaffected by beam direction uncertainty. The aerogel ring reconstruction could result inaccurate due to the small part of the ring covered; in this case a tracking system may help.

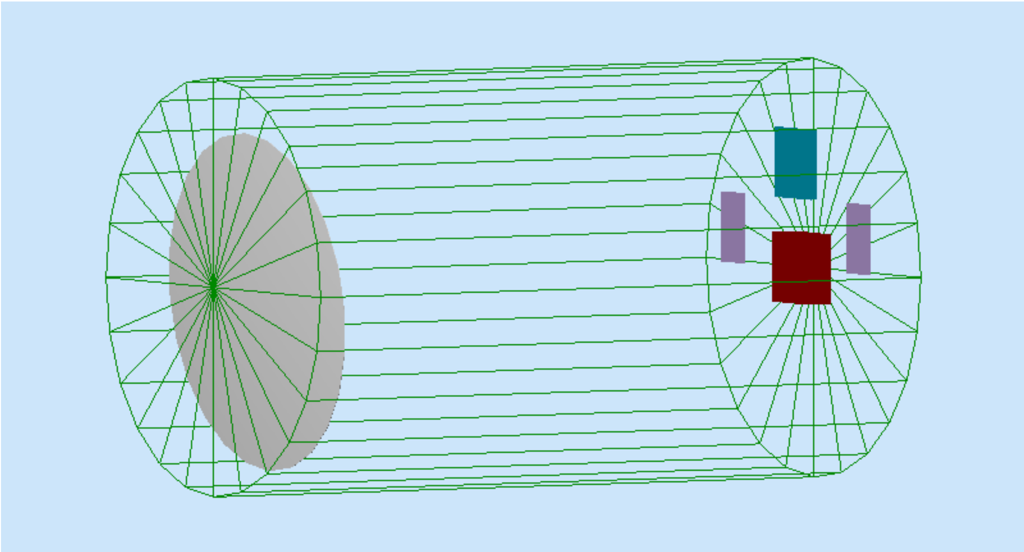

Fig 1: The gas tank (in green) is a cylinder 1 m long and with radius of 30 cm; the aerogel tiles are placed close to the beam entrance; in blue are four PMTs or SiPMs (5x5 cm^2 each), which are enough to collect the full ring from the gas; the same four photon detectors can be reused, in a different arrangement (in violet), to collect a small (but likely significant) part of the aerogel's photons.

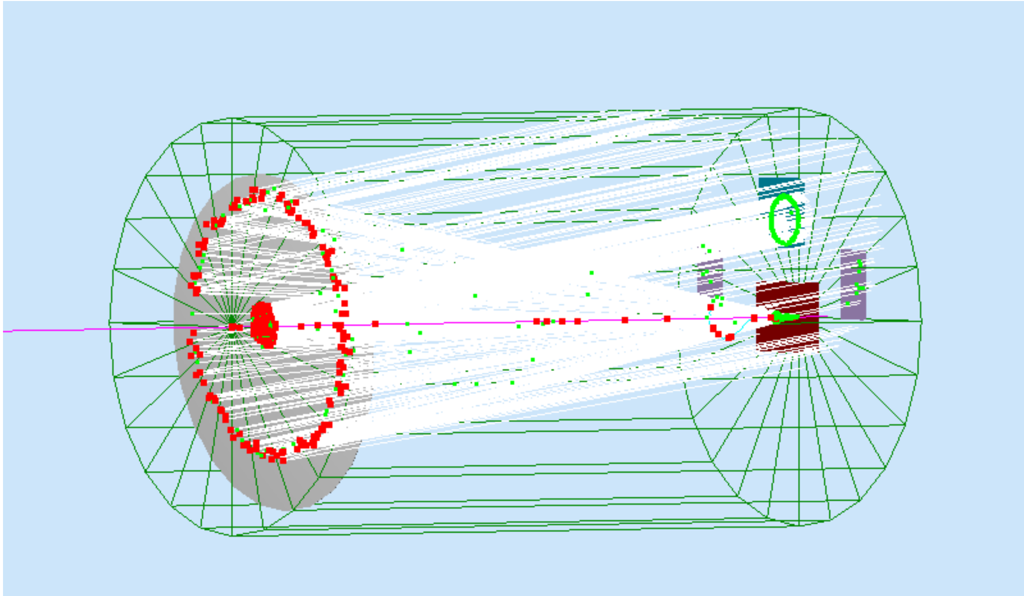

Fig 2: Same configuration of Fig. 1 with a pion of 6 GeV/c passing trough .

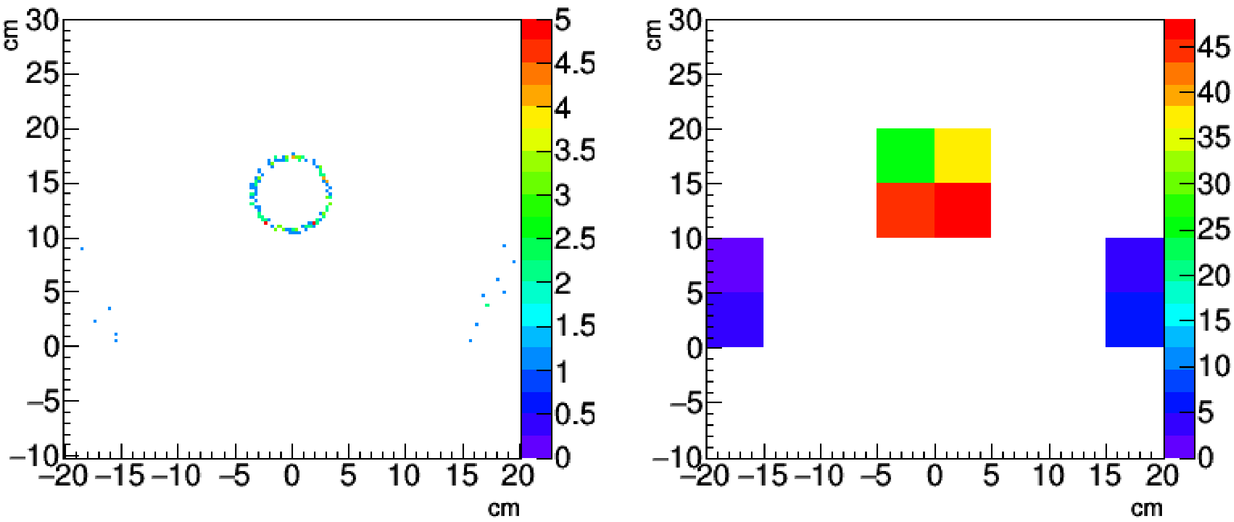

Fig 3: 4 photon detectors (PMTs, 5x5 cm^2) cover the whole gas ring; the same 4 detectors can be used in different runs to cover a small part of the aerogel ring.

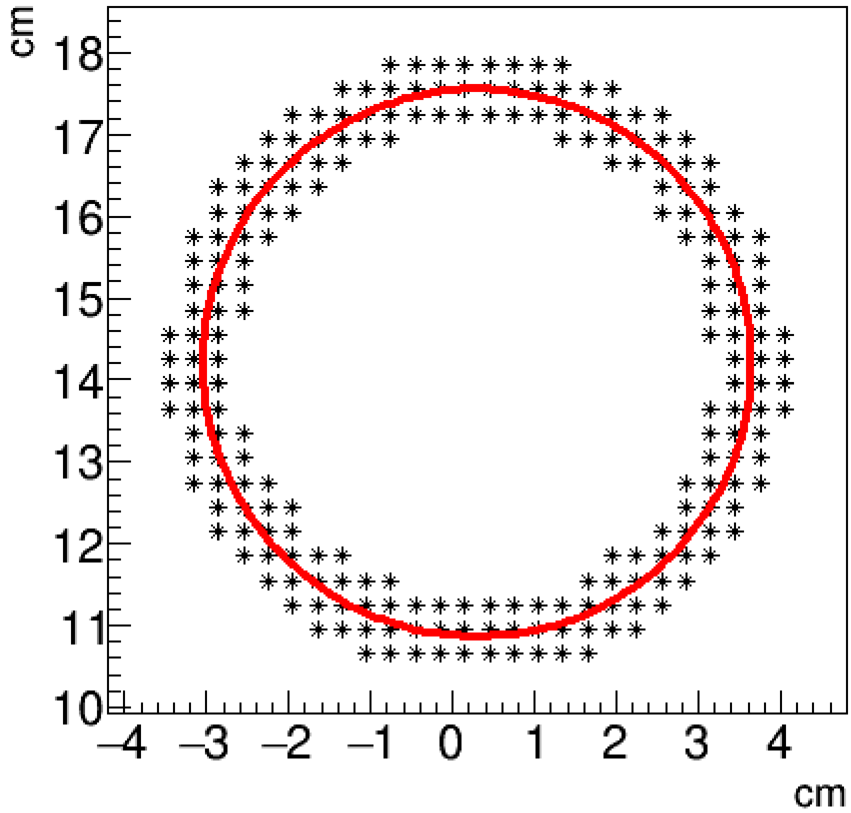

Fig. 4: The fit of the gas ring for 500 cumulated tracks of a pion at 6 GeV/c.

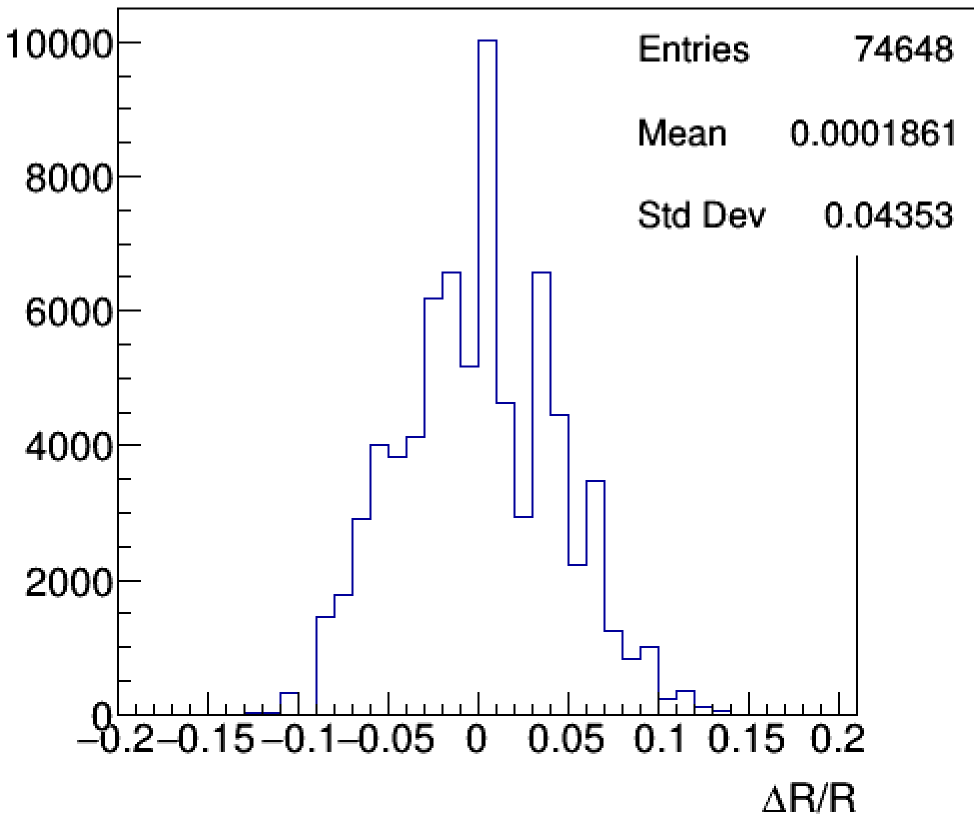

Fig. 5: Resolution on the ring's radius of Fig. 5 .

A couple of tracking chambers and/or a collimator should be added to the configuration if we want to use the MC implemented reconstruction algorithm, which requires a certain precision on the track entering the radiators.